

A loading/tuning coil for 137 kHz antennas

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Doubtless the most significant and difficult challenge for the urban amateur intent on doing some low frequency (LF) transmission is the antenna problem. Few of us have access to a pair of 30 m masts spaced hundreds of metres apart, or a nearly ideal ground through the steel hull of a ship, for instance.

However, we are fortunate in this country as much good theoretical and practical LF work has already been published by Australian (References 1, 2 and 3), New Zealand, and European amateurs and experimenters. Indeed, the RSGB Handbook (Reference 4) has contained an LF chapter for the past few editions, where may be found details of the sort of equipment and techniques needed to radiate an effective LF signal from an ordinary suburban location. Much of what follows is derived from these sources.

A back-yard inverted-L or T antenna,

worked against ground, or counterpoise, can only be a few percent of a wavelength long at LF, and so the radiator must operate far below its natural resonant frequency. We therefore require a large amount of inductive and/or capacitive loading in order to present a resistive load to the transmitter. Such electrically small antennas are very inefficient, typically 0.2%. Never-the-less, our UK, European and NZ colleagues have achieved good results from home stations.

The usual 'standing-wave' concept of understanding HF antennas cannot readily be applied to an extremely short

radiator at LF. It is conjectured that vertically polarised radiation is produced by the combined electric field established between the top wire and ground, and the displacement current* between the top wire and ground. The voltage on the wire is almost equal along its length, whereas the current will be maximal at the feed point, falling to zero at the far end(s) of the wire.

To find the amount of loading inductance required, the natural capacitance of the radiating wire is first determined. A workable 'rule of thumb' for estimating the total capacitance of

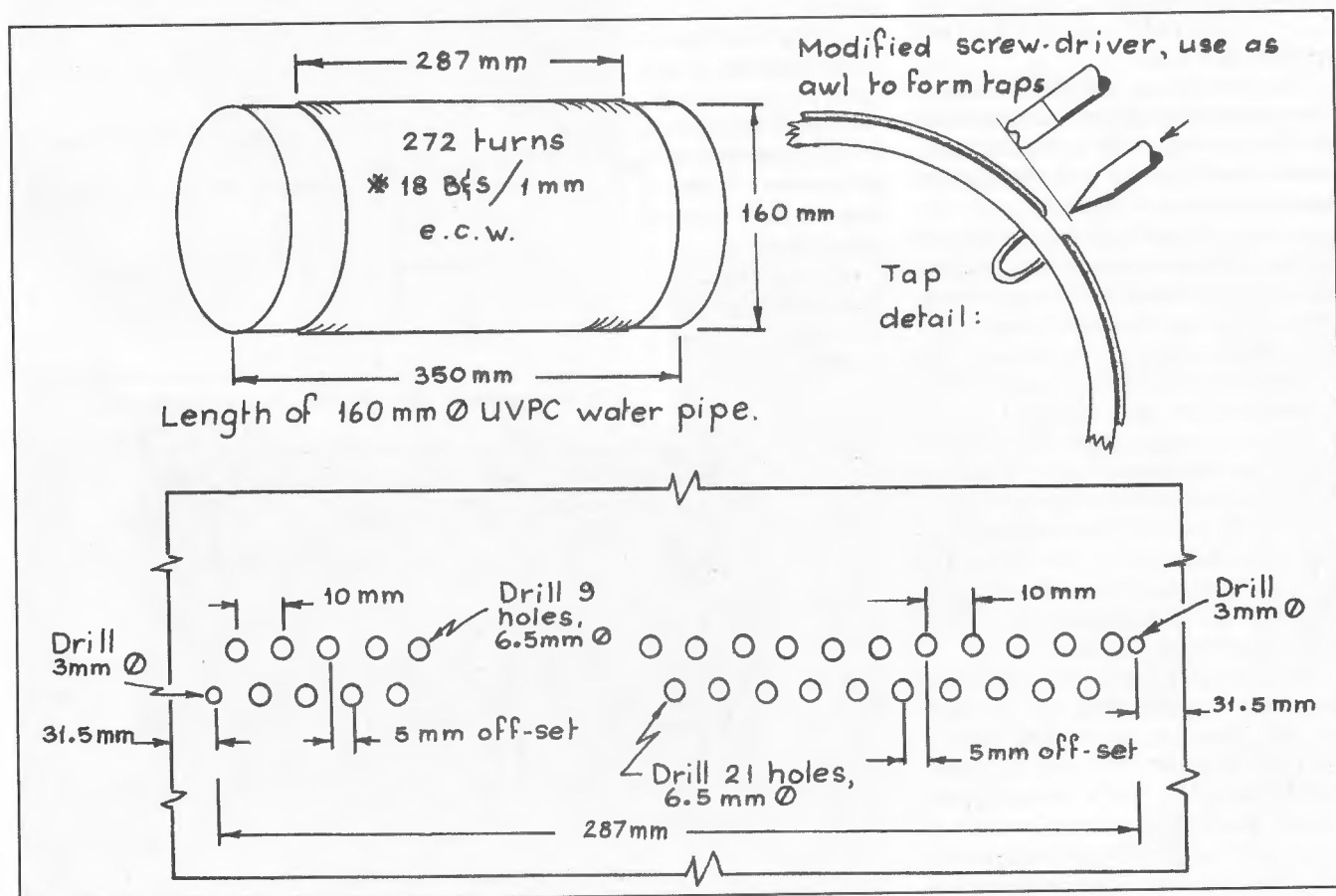


Figure 1: The layout of the coil, drilling for the taps, and how to form the taps.

the radiator (that I have found applies quite well) is given in Reference 4, which gives a figure of 6 pF per vertical metre, and 5 pF per horizontal metre of ordinary 7/.067 mm PVC covered electrical wire.

Next time you see an LF beacon antenna site: have a good look at the configuration. Notice that the horizontal top part of the T is (generally) composed of multiple wires that run out from the feed wire, these separated by spreaders of perhaps a few metres in length, thus significantly increasing the capacity of the antenna, thereby reducing the amount of loading inductance required.

It is quite possible that some amateurs may have enough space for an inverted L or T composed of, perhaps, 12 metres vertical and 42 m horizontal (total 54 m). The natural capacitance is estimated: $12 \times 6 = 72$ pF, and $42 \times 5 = 210$ pF. Total = $72 + 210 = 282$ pF. We therefore need to 'tune' our 282 pF with an appropriate amount of loading inductance in order to bring the system into resonance at (say) 137 kHz.

$$L = 25330 / (f \text{ MHz}^2 \times C) \text{ (Ref. 5)}$$

where L = inductance in uH, C = capacitance in pF.

$$L = 25330 / (0.137^2 \times 282) = 4785.7 \mu\text{H}, \text{ rounded to } 4.8 \text{ mH}.$$

To allow for any changes in antenna capacitance, it is a good plan to make the loading coil (or helix) rather larger than calculated, so I shall describe construction of a 5.2 mH coil.

A study of practical coils constructed by our overseas colleagues (and here, see Reference 3) makes fascinating reading. Some specimens, using edge-wound copper strip, or large diameter Litz wire, are truly legendary. Big is good. And bigger is better. Just where do we draw the line?

Let me try an example. The 5.2 mH tapped coil shown in Photo 1 is wound upon a 350 mm length of ordinary 160 mm diameter UVPC pipe. Measured Q at 137 kHz is 280 - pretty much as expected. Its RF resistance at 137 kHz is therefore about 16 ohms.

Assuming an optimistic radiation resistance of 0.05 ohm, and an earth ground resistance of 10 ohms ($0.05 + 16 + 10$ ohms, all effectively in series - see Reference 2), 100 W of input power should produce an antenna current of about 1.96 A (192 mW radiated power). Now, if a second coil of larger dimensions and thicker wire with a Q of 560 (0.05

+ 8 + 10 ohms) were substituted, then current should rise to 2.35 A (276 mW radiated), where, for the same input power level, the radiated signal would increase by about 1.6 dB.

Coil

My aim in this instance was to make an acceptably efficient coil of reasonable dimensions using readily available materials and tools. 160 mm white UVPC storm water pipe is quite good electrically, easily machinable, and obtainable in short lengths from Bunnings. 1 mm ecw is a common wire size used by transformer makers, armature winders and other electrical trades. And ordinary round 1 mm wire is easily 'workable', so that tapping points may be readily made during the winding process.

The oft quoted, and quite accurate Wheeler's (metricated) formula for finding the inductance of a single-layer solenoid coil is:

$$L = (d^2 \times n^2) / (457.2d + 1016l) \text{ (Reference 4, pA3)}$$

where L is in uH, d = diameter in mm, n = number of turns, and l = coil winding length in mm.

My coil has 272 turns, winding length 287 mm, 160 mm diameter.

$$\text{Substituting: } L = (160^2 \times 272^2) / [(457.2 \times 160) + (1016 \times 287)]$$

$$= 5192 \mu\text{H}, \text{ rounded to } 5.2 \text{ mH}.$$

The measured inductance at 1, 137 and 250 kHz agree very closely with this result.

Method

A suggested way of winding the coil is pictured in Photo 2. The wire spool is supported upon a wood frame with a length of round timber (e.g. part of an old broom handle) passed through the spool's centre. The frame is clamped upon the 'work-mate' saw bench with two G clamps (not visible, behind the bracing panel of the frame).

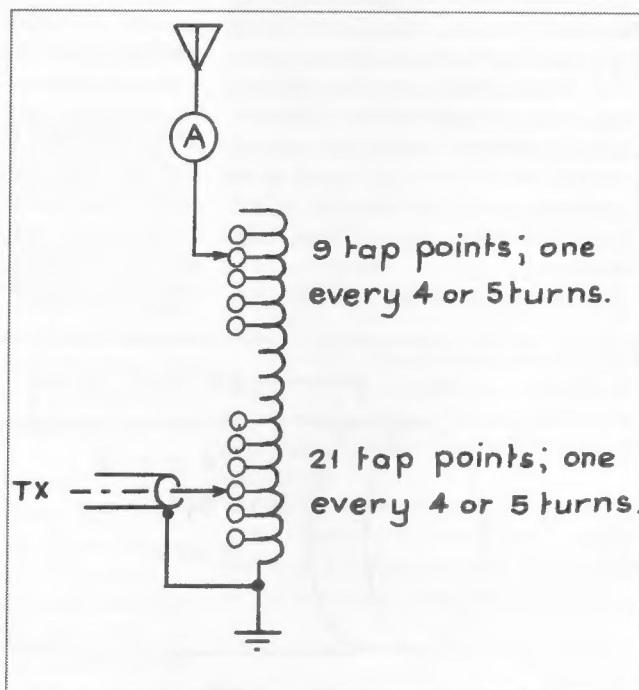


Fig. 2: A suggested configuration for using the loading/tuning coil.

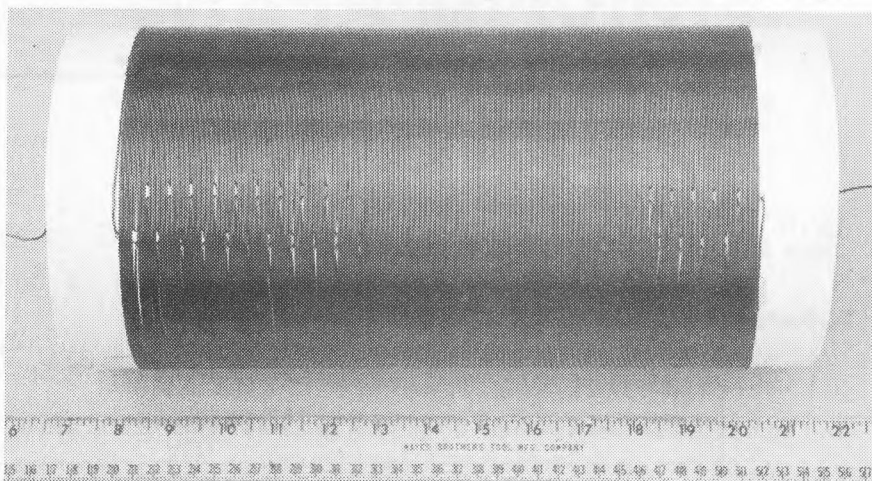


Photo 1: The completed loading/tuning coil for 137 kHz.

To prevent damage to the winding, two strips of carpet should be fixed upon the bench leaves with masking tape, as shown. The coil former may now be placed upon the leaves, and the coil wound on, as depicted in Photo 2.

The length of wire required in metres may be estimated by $(\pi \times d \times n) / 1000$ which substitutes to $(3.142 \times 160 \times 272) / 1000 = 136.7$ m, which is then rounded up to 140 m to allow for tails, taps and errors. Self fluxing ecw should be used if available.

Taps are formed by carefully pressing the wire into the 6.5 mm holes, stagger spaced 5 mm, pre-drilled in the former, as shown in Figure 1 (the drawing is a guide only, actual dimensions are not critical - add extra taps if required). A useful tool, or awl, for the job may be made from an old screw-driver. A smooth U-shaped notch should be filed in the blade so that the wire is formed into a loop as the awl is pushed into the hole with just sufficient travel to form a solderable tap, as shown in Figure 1 and Photo 3.

One handy benefit of making internal

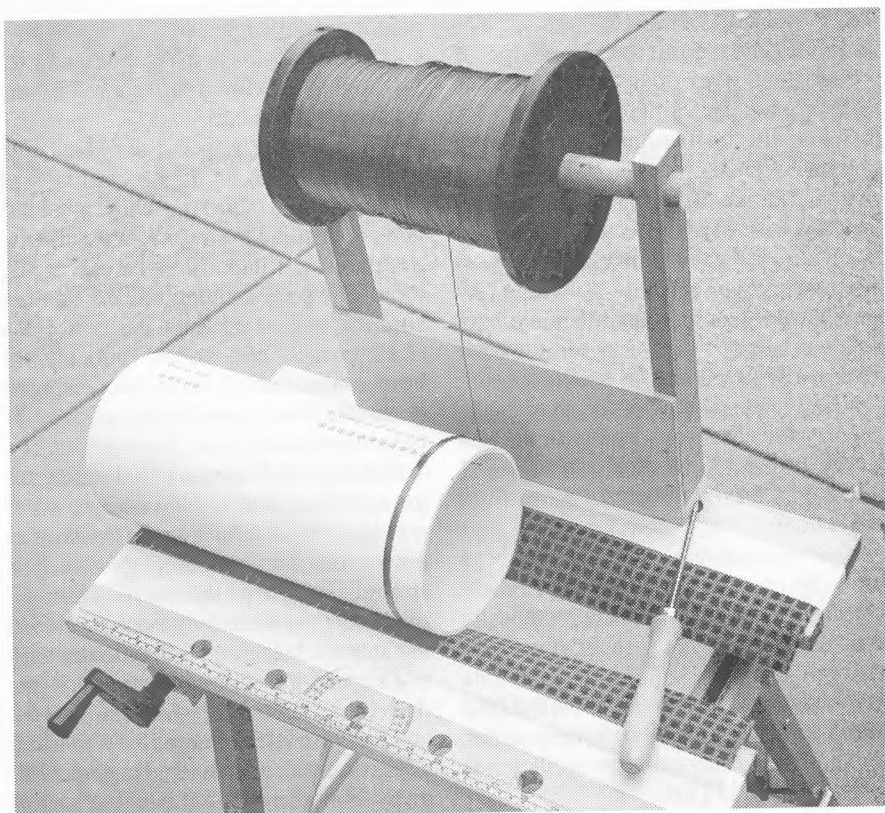


Photo 2: The set up for coil winding.

tapping points in this manner is that the coil is prevented from unspooling at each tap, so the worker can take a break at regular intervals, as needed (except, of course, for

the 'long haul' in the middle section of the coil).

Operation

A suggested configuration is shown in Figure 2. It would be prudent to initially adjust the coil inductance for resonance, and find the 50 ohm connection point

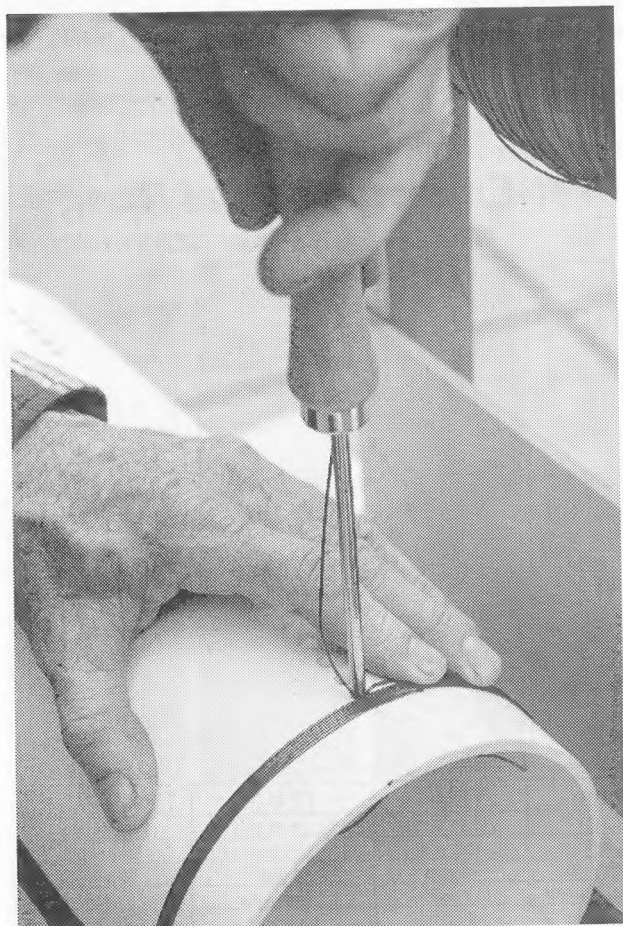


Photo 3: Forming a coil tap.

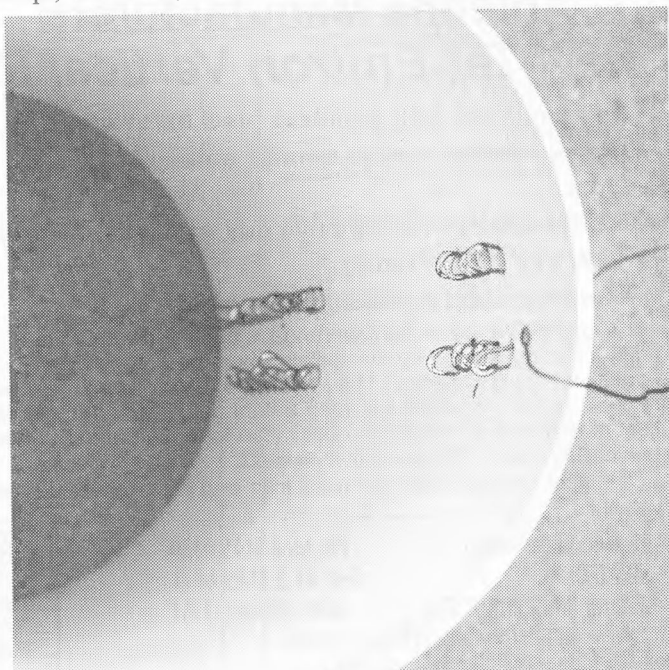


Photo 4: A view inside the coil former showing the coil taps.

using a small-signal test set-up. For example, the RF resistance bridge of Reference 6 works well at 137 kHz, as no doubt other patterns do too.

When the coil inductance and the antenna capacitance are resonated, and matched into a 50 ohm signal source, a (perhaps surprisingly) high RF potential is obtained at the top of the coil, even when energizing the antenna with a few milliwatts. So an initial adjustment may be done using a signal generator (that covers 137 kHz), and an oscilloscope.

Using a suitable length of coax cable, connect the generator's output to the coil in lieu of the TX, as shown in Figure 2, initially about one quarter way up from the bottom.

Now position the oscilloscope's X10 probe tip near the top of the coil (loosely capacitively coupled, but not physically connected). Sweep the generator's frequency through 137 kHz, altering the antenna connection near the top end of the coil, and the coax connection near the bottom, so that the amplitude displayed on the oscilloscope peaks at about 137 kHz.

At the milliwatt power level, we can put our hands inside the coil and alter the connections with no risk of burning fingers! These two adjustments interact, so some

juggling may be required.

If found necessary, the coil may be inverted to provide more tapping points at the top of the coil.

When doing these adjustments, we soon realise that the high potential end of the coil (and hence the whole antenna) is very sensitive to stray capacity effects, such as one's hand anywhere near the top of the coil, which confirms that the antenna insulators must be first class (References 7 and 8), and there should be a minimum of dielectric material (example tree limbs) in the vicinity of the antenna wire.

Having thus found an initial setting for the taps (and that we have approval to use the new LF band), some transmitter power may be cautiously applied. It is strongly suggested that an RF ammeter of appropriate sensitivity be connected in the antenna lead as an aid to final tuning and matching - "its amps up the stick that does the trick".

Always cut carrier before making adjustments, and keep fingers well away from the coil and antenna lead. A fluorescent tube or neon lamp should be permanently installed near the 'hot' end of the coil, whose glow will warn people to keep clear.

References and Further Reading

1. <http://member.melbpc.org.au/~jadcock/>
2. <http://users.tpg.com.au/ldbutler/>
3. "Experimental Stations on 196 kHz 1531 m"; J Adcock VK3ACA, Amateur Radio, July 1984.
4. Radio Communication Handbook; RSGB, 8th edition.
5. Any older edition of the ARRL Handbook; e.g. 1966 edition, p 542.
6. "An RF Resistance Bridge"; Diamond, Amateur Radio, July 1999.
7. "How long is a piece of wire"; J Wiseman, Wireless World, April 1985, pp 24, 25.
8. "Anybody seen our ship?"; J Wiseman, Nautical Review, May 1979.

*James Clerk Maxwell stated in 1865 that any change in the electric flux in any region is equivalent to an electric current in that region, and he called this a displacement current, to distinguish it from a conventional conduction current. This displacement current produces a magnetic field exactly as if it had been produced by a conduction current (Reference: Electrical Technology; E Hughes, 4th edition, p 171. See also: The Man Who Changed Everything - The Life of James Clerk Maxwell; B Mahon, published by Wiley, pp 106, 125-6, 178).

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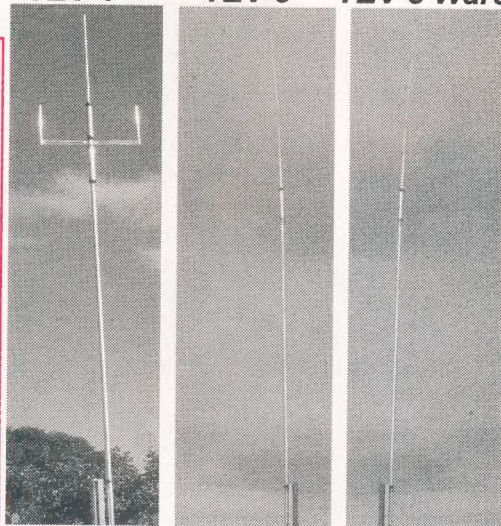
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